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# The Interaction Between Vortices and a Biomimetic Flexible Fin

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**Abstract.** The fluid-structure interaction of flexible bodies in steady and unsteady flow is a key area of interest for the development of underwater vehicles. In the design of marine vehicles the flow can often be seen as an obstacle to overcome, whilst in nature a fish interacts with the flow and is capable of achieving a high level of efficiency. Therefore by understanding how fish – or flexible bodies – interact with the flow we may be able to achieve a better level of co-operation between our vehicles and their environment, potentially attaining a better efficiency in design.

A large part of the interaction between a fish and the flow is its sensing capabilities. A fish is able to sense the flow around it and react to the fluid structures that are present, such as turbulence or vortices; one of its senses that may provide information for this is a sensory array called the lateral line. If an underwater vehicle had a similar hydrodynamic sensing system it may be able to react to the fluid flow autonomously. With the emergent technology of MEMs sensors [1] it will be possible to sense the flow in ways other than using visual or sonar technology.

There is a gap in the literature that investigates the fluid flow over the body, especially in turbulent flows. Focus has been on the flow around a body in steady flow [2], where drag reduction by the motion of the body and therefore the boundary layer behaviour was investigated; the boundary layer of an oscillating body stays attached, corroborating swimming fish experiments [3]. Studies into the wake behind foils [4-7] have described and quantified the different wake patterns that are produced dependent on the frequency and amplitude of the foil, or on the position of the foil with respect to an oncoming vortex street. The different patterns that can occur at the leading edge of a rigid aerofoil when interacting with a vortex street have been classified [8]. Presented here is a study on the fluid-structure interaction of a flexible biomimetic fin in a Kármán vortex street. The effect of the fin on the wake behind a cylinder is considered; specifically changes in vortex speed, strength and size. This provides insights on the features available to sense in the flow and how flow is reconfigured due to the presence of a flexible body.

A silicone rubber fin with a biomimetic stiffness profile [9], of chord length 120 mm and an aspect ratio of 1 was placed in a flow channel (1300 x 300 x 240 mm). A 45 mm diameter circular cylinder was placed 150 mm upstream of the fin. The cylinder was used to create a Kármán vortex street, a fluid phenomenon that has been extensively studied. It is a common occurrence in natural water-ways, caused by the fluid flowing around bluff bodies. Two-dimensional digital particle

image velocimetry (DPIV) was used to visualise the flow. A high-speed CCD camera was used to capture the images of the seeded particles in the flow (Vestosint 1301, mean diameter 100 µm), illuminated by a solid state laser of wavelength 532 nm. Insight 3G software was used for capture and processing of the images (field of view 308 x 247mm).

Initial results show that vortices in the wake of the cylinder, with no other obstacle introduced, travel downstream at a higher speed than that of the freestream: 0.42 m/s as opposed to 0.3 m/s. With the biomimetic fin placed in the Kármán vortex street the velocity of the vortices travelling downstream from the cylinder towards the fin was much lower: 0.18 m/s. By tracking a vortex down the length of the fin it was calculated that it accelerated; by the trailing edge the vortex was travelling at approximately the freestream velocity and in the wake the average vortex velocity was 0.33 m/s. In addition to studying the vortices' downstream velocity, the variations in their strength and size (before, along and after the fin) have been determined.

Incident vortices have been shown to deform before the leading edge of a foil [8] suggesting the presence of a bow wake, which may contribute to their slowing. We believe that the shape of the fin causes a positive pressure gradient near the nose, which slows the flow down. The flow then accelerates around the fin as the effect of this positive pressure gradient is diminished and a favourable pressure gradient is encountered. This set of experiments is a first step towards better understanding the fluid flow interaction with a flexible body in steady and unsteady flow. The knowledge gained from these experiments could allow for better modelling and design of biomimetic submersibles, particularly if they intend to use flow detection as a means for locomotion and control optimisation.

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